BAYOU LACASSINE WATERSHED TMDL FOR DISSOLVED OXYGEN INCLUDING WLAS FOR TWO POINT SOURCE DISCHARGES

SUBSEGMENT 050601

SURVEYED AUGUST AND SEPTEMBER 1999

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EXECUTIVE SUMMARY

This report presents the results of a watershed based, calibrated modeling analysis of Bayou Lacassine. The modeling was conducted to establish a dissolved oxygen TMDL for the Bayou Lacassine watershed. The model extends from Interstate 10 to the confluence of Bayou Lacassine with the Intracoastal Waterway. Bayou Lacassine is located in southern Louisiana and it's watershed includes the following tributaries: East and West Bayou Lacassine, Bayou Chene, Thornwell Drainage Canal and several unnamed tributaries. The watershed is 398 square miles in area at its intersection with the Intracoastal Waterway. The Bayou Lacassine watershed is in the Mermentau River Basin and includes Water Quality Subsegments 050601 and 050603. The area is sparsely populated outside its small municipalities, and land use is dominated by agriculture. A total of two sewage treatment facilities were included in the modeling effort.

Input data for the calibration model were developed from the LDEQ Reference Stream Study, data collected during the 1999 intensive surveys, data collected by LDEQ at one ambient monitoring station in the watershed, DMRs and permits for each of the point source dischargers, USGS drainage area and low flow publications, and previous field studies conducted by LDEQ in the area. A satisfactory calibration was achieved. For the projection models, data were taken from the current discharge permits and ambient temperature records. The Louisiana Total Maximum Daily Load Technical Procedures (revised 1999) have been followed in this study.

Modeling was limited to low flow scenarios for both the calibration and the projections since the constituent of concern was dissolved oxygen (DO) and the available data was limited to low flow conditions. The model used was QUAL-TX, which was selected since it offers the ability to model branched systems and has been used successfully in Louisiana in the past.

Bayou Lacassine, Subsegment 050601, was on the 1998 303(d) list of impaired water bodies requiring the development of TMDLs. The subsegment was ranked priority one on the 1998 list. The suspected causes of impairment were nutrients, organic enrichment/low DO, suspended solids, turbidity, and metals. This TMDL addresses the organic enrichment/low DO impairment. The TMDL for each season is summarized in the following table:

	Allowable oxygen demanding load (lbs/day)	
	Summer (Mar - Nov)	**Winter (Dec - Feb)**
Wasteload allocation for point sources	109	84
Margin of safety for point sources	28	22
Load allocation for manmade NPS	6418	10427
Margin of safety for manmade NPS	713	1159
Load allocation for natural NPS	23946	29074
Margin of safety for natural NPS	0	0
Total maximum daily load	31214	40766

The results of the summer and winter projections show that reductions in oxygen demanding loads are needed for both point sources and nonpoint sources in order for the DO standards to be met in all portions of the Bayou Lacassine system. The point source upgrades and nonpoint source reductions needed are summarized in the following table:

	Point Source Upgrades		**Reductions in Manmade Nonpoint Source Loads**			
	Town of Welsh WWTP	**Lacassine High School WWTP**	**East Bayou Lacassine**	**West Bayou Lacassine**	**Bayou Lacassine upstream of Hwy 14**	**Bayou Lacassine downstream of Hwy 14**
Summer	Upgrade*	None	67%	0%	81%	0%
Winter	Upgrade*	None	5%	0%	41%	0%

* Upgrade to discharge concentrations of 5 mg/L $CBOD_5$, 2 mg/L ammonia nitrogen, 1 mg/L organic nitrogen, and 5 mg/L DO.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program are used to develop the state's biennial 305(b) report (*Water Quality Inventory*) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d) list. The sampling schedule for the first five-year cycle is shown below.

1998 – Mermentau and Vermilion-Teche Basins
1999 – Calcasieu and Ouachita River Basins
2000 – Barataria and Terrebonne Basins
2001 – Lake Pontchartrain Basin and Pearl River Basin
2002 – Red and Sabine River Basins
(Atchafalaya and Mississippi Rivers will be sampled continuously.)
Mermentau and Vermilion-Teche Basins will be sampled again in 2003.

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ACKNOWLEDGEMENTS

This TMDL was performed by a multidisciplinary team of people at FTN Associates with assistance from LDEQ personnel, subcontractors, and other government agencies. The LDEQ project manager was Dick Duerr and the FTN project manager was Dennis Ford. The guidance and assistance from Mr. Duerr throughout this project was extremely valuable. Dr. Ford provided general oversight and supervision for all phases of the project.

The reconnaissance survey was performed by FTN personnel (Philip Massirer and Mark Uguccioni) and the LDEQ project manager (Dick Duerr), with assistance from subcontractors.

The intensive survey was performed by several FTN personnel (Philip Massirer, Gerry Conley, Mark Uguccioni, and Cassandra Prewett) with assistance from subcontractors. The subcontractor personnel included Troy Dupre, Ricky Billiot, and Gary Guidry from T. Baker Smith & Sons in Houma, LA; and Kevin Hennigan from Consumer Environmental Services in Baton Rouge, LA.

Laboratory analyses of water samples were performed by Specialized Assays, Inc. in Nashville, TN.

Meteorological data were provided by the Louisiana Office of State Climatology in Baton Rouge, LA. Stage data for Bayou Lacassine at Highway 14 during the surveys were retrieved from the USGS website.

Historical water quality data for the lower end of Bayou Lacassine were provided by Wayne Syron of the Lacassine National Wildlife Refuge. Mr. Syron also provided valuable local knowledge of the Bayou Lacassine system.

Data analyses and preparation of the survey report were performed by several FTN personnel including Pat Downey, Philip Massirer, Gerry Conley, Christina Laurin, Mark Uguccioni, Cassandra Prewett, Sharon Baker, and others.

The water quality modeling and TMDL calculations and preparation of this report were done by Christina Laurin with guidance from Philip Massirer.

1.0 INTRODUCTION

The 1998 303(d) list (LDEQ, 1998a) cited Bayou Lacassine, Subsegment 050601, as being impaired due to organic enrichment/low DO and nutrients and required the development of a Total Maximum Daily Load (TMDL) for DO. The subsegment was ranked priority one on the 1998 list. A calibrated water quality model was developed and projections were modeled to quantify the point source and non-point source waste load reductions, which would be necessary in order for Bayou Lacassine to comply with its established water quality standards and criteria. This report presents the results of that analysis.

2.0 STUDY AREA DESCRIPTION

2.1 General Information

The model extends from Interstate 10 to the confluence of Bayou Lacassine with the Intracoastal Waterway. The Bayou Lacassine watershed includes the following tributaries: East and West Bayou Lacassine, Bayou Chene, Thornwell Drainage Canal and several unnamed tributaries. The drainage area for the watershed is 398 square miles (USGS, 1971). The watershed contains Water Quality Subsegments 050601 (Bayou Lacassine) and 050603 (Bayou Chene). The area is sparsely populated outside its small municipalities and land use is dominated by agriculture (Table 2.1). Two sewage treatment facilities were included in the modeling effort. Maps of the study area are presented in Appendix A.

Table 2.1. Land uses in Segment 0506 (LDEQ, 1993).

Land Use Type	% of Total Area
Urban	0.8
Extractive	0.3
Agricultural	65.7
Forest Land	1.8
Water	2.2
Wetland	29.1
Barren Land	0.0
TOTAL	100.0

2.2 Water Quality Standards

The water quality criteria and designated uses for the Bayou Lacassine watershed are shown in Table 2.2.

Table 2.2. Water quality numerical criteria and designated uses (LDEQ, 1999a).

Subsegment	050601
Stream Description	Bayou Lacassine -Headwaters to Intracoastal Waterway
Designated Uses	ABCF
Criteria:	
Chloride	90 mg/L
Sulfate	10 mg/L
DO	5 mg/L: DEC-FEB 3 mg/L: MAR-NOV
pH	6.0 - 8.5
Temperature	32 °C
TDS	400 mg/L

USES: A – primary contact recreation; B – secondary contact recreation; C – propagation of fish and wildlife; D – drinking water supply; E – oyster propagation; F – agriculture; G – outstanding natural resource water; L – limited aquatic life and wildlife use.

A DO use attainability analysis (UAA) for the Mermentau River Basin was performed by LDEQ to provide the basis for a revision to the DO criteria in Bayou Lacassine and other streams in the Mermentau River basin (LDEQ, 1998b). The DO criteria recommended in this UAA were adopted as the water quality standards and are listed in Table 2.2.

2.3 Wastewater Discharges

All but two of the dischargers located in the Bayou Lacassine watershed were considered too far away or too small to directly impact Bayou Lacassine. The two point source dischargers that were included in the model were Lacassine High School and the Town of Welsh wastewater treatment plants (WWTP). The approximate locations of these discharges are shown on Figure A.2 (sampling points LHS and Wel). The permits record, permit applications, and Discharge Monitoring Reports (DMRs) for these facilities were examined and appropriate input information for the calibration and projection modeling runs was derived to the maximum extent possible.

Relevant information on these two discharges is listed below:

	Lacassine High School	Town of Welsh
Permit number:	LAG540398	LA0020591
Receiving stream:	West Bayou Lacassine	East Bayou Lacassine
Design flow:	0.0092 mgd	0.475 mgd
Permit limits:	30 mg/L BOD_5	10 mg/L BOD_5
Treatment:	Extended aeration package plant	1 cell oxidation pond

2.4 Water Quality Conditions/Assessment

According to the 1998 305(b) Water Quality assessment for Louisiana, primary and secondary contact recreation uses are being fully supported in Subsegment 050601, Bayou Lacassine from the headwaters to the Intracoastal Waterway. Propagation of fish and wildlife is not being supported. There is insufficient data to determine if the agriculture use is being met (LDEQ, 1998a). The suspected causes of impairment are nutrients, organic enrichment/low DO, suspended solids, turbidity, and metals. The subsegment is on the 1998 303(d) list and is scheduled for 1999 TMDL development.

2.5 Prior Studies

Previous water quality data collected for Bayou Lacassine and tributaries include the following:

1. Monthly data collected by LDEQ for "Bayou Lacassine near Lake Arthur" (station 98) for 1978 to present (some months missing). This station is located at the Highway 14 bridge (same location as BL-3 on Figure A.2).
2. A reconnaissance and intensive survey of East Bayou Lacassine downstream of the Town of Welsh WWTP. The reconnaissance was performed by LDEQ in July 1991 (LDEQ, 1991) and the intensive survey was performed by LDEQ in June 1992 (LDEQ, 1994). A wasteload modeling study was planned but never performed.
3. Assessment data collected by LDEQ for Bayou Chene at the Highway 99 bridge during June-December 1998.
4. Semi-monthly data collected by the U.S. Fish and Wildlife Service at 3 locations along Bayou Lacassine within the Lacassine National Wildlife Refuge during 1988-99.

3.0 DOCUMENTATION OF CALIBRATION MODEL

3.1 Model Description and Input Data Documentation

3.1.1 Program Description

"Simulation models are used extensively in water quality planning and pollution control. Models are applied to answer a variety of questions, support watershed planning and analysis and develop total maximum daily loads (TMDLs) . . . Receiving water models simulate the movement and transformation of pollutants through lakes, streams, rivers, estuaries, or nearshore ocean areas . . . Receiving water models are used to examine the interactions between loadings and response, evaluate loading capacities (LCs), and test various loading scenarios . . . A fundamental concept for the analysis of receiving waterbody response to point and nonpoint source inputs is the principle of mass balance (or continuity). Receiving water models typically develop a mass balance for one or more constituents, taking into account three factors: transport through the system, reactions within the system, and inputs into the system." (EPA 841-B-97-006, pp. 1-30)

The model used for this TMDL was QUAL-TX, "a steady-state one-dimensional water quality model that has been developed by the Water Quality Standards and Evaluation Section of the Texas Water Commission. It is a modified version of QUAL-II. The original QUAL-II model was developed by Water Resources Engineers (now Camp Dresser & McKee) for the United States Environmental Protection Agency. Since that time, many modifications have been made to QUAL-II by many people. QUAL-TX is a user oriented model incorporating many of those modifications and is intended to provide the basis for evaluating waste load allocations in the State of Texas." (QUAL-TX User's Manual, rev. 1990). QUAL-TX was selected since it offers the ability to model branched systems and it has been used successfully in Louisiana in the past.

"The development of a TMDL for DO generally occurs in 3 stages. Stage 1 encompasses the data collection activities. These activities may include gathering such information as stream cross-sections, stream flow, stream water chemistry, stream temperature and DO at various locations on the stream, location of the stream centerline and the boundaries of the watershed which drains into the stream, and other physical and chemical factors which are associated with the stream. Additional data gathering activities include gathering all available information on each facility which discharges pollutants into the stream, gathering all available stream water quality chemistry and flow data from other agencies and groups, gathering population statistics for the watershed to assist in developing projections of future loadings to the water body, land use and crop rotation data where available, and any other information which may have some bearing on the quality of the waters within the watershed. During Stage 1, any data available from reference or least impacted streams, which can be used to gauge the relative health of the watershed, is also collected.

"Stage 2 involves organizing all of this data into one or more useable forms from which the input data required by the model can be obtained or derived. Water quality samples, field measurements, and historical data must be analyzed and statistically evaluated in order to determine a set of conditions, which have actually been measured in the watershed. The findings are then input to the model. Best professional judgement is used to determine initial estimates for parameters, which were not or could not be measured in the field. These estimated variables are adjusted in sequential runs of the model until the model reproduces the field conditions which were measured. In other words, the model produces a value of the DO, temperature, or other parameter which matches the measured value within an acceptable margin of error at the locations along the stream where the measurements were actually made. When this happens, the model is said to be calibrated to the actual stream conditions. At this point, the model should confirm that there is an impairment and give some indications of the causes of the impairment. If a second set of measurements is available for slightly different conditions, the calibrated model is run with these conditions to see if the calibration holds for both sets of data. When this happens, the model is said to be verified.

"Stage 3 covers the projection modeling which results in the TMDL. The critical conditions of flow and temperature are determined for the waterbody and the maximum pollutant discharge conditions from the point sources are determined. These conditions are then substituted into the model along with any related condition changes which are required to perform worst case scenario predictions. At this point, the loadings from the point and nonpoint sources (increased by an acceptable margin of safety) are run at various levels and distributions until the model output shows that DO criteria are achieved. It is critical that a balanced distribution of the point and nonpoint source loads be made in order to predict any success in future achievement of water quality standards. At the end of Stage 3, a TMDL is produced which shows the point source permit limits and the amount of reduction in man-made nonpoint source pollution which must be achieved to attain water quality standards. The man-made portion of the NPS pollution is estimated from the difference between the calibration loads and the loads observed on reference or least impacted streams." (LDEQ, 1999b).

The model was hydrologically calibrated to the August 1999 survey measurements of streamflow and chlorides. Water quality parameters and coefficients were then established based on available data and best professional judgement. The calibration model output was then compared to the 1999 field survey measurements of water quality and the calibration was determined to be successful.

3.1.2 Model Schematic or Vector Diagram

A vector diagram of the modeled area is presented in Appendix B. The vector diagram shows the locations of survey stations, the reach/element design, the locations of modeled tributaries and POTWs, and the locations of tributaries contributing flow but not modeled (e.g., Bayou Chene). The modeled streams were divided into 1-mile long reaches so that depths and widths could be varied all along the streams.

3.1.3 Hydrology and Stream Geometry and Sources

The flows used in the model were those measured during the August 1999 field survey. Although most of the flows measured during the field survey were in the upstream direction, there were downstream flows measured at the headwaters (EBL-1 and WBL-1). These flows were used for the headwater flows in the model. Station WBL-1 is downstream of the Lacassine High School discharge. However, there was no discharge to West Bayou Lacassine when flow was measured at WBL-1. During the field survey, flow measurements were also made at the point source discharges. These measured flows were used in the model for the point sources.

Flows were negative (i.e., upstream) in all of the tributaries modeled as point sources. In the model, the flows for UT1, UT2, and Thornwell Drainage Canal were set to zero. These tributary flows were set to zero because their drainage areas are small and their net downstream flows over an entire tidal cycle were assumed to be negligible. A downstream flow was estimated for Bayou Chene based on the area of its watershed and areal flows for the stations at the headwaters of

East and West Bayou Lacassine measured during the August field survey. The areal flow for East Bayou Lacassine at EBL-1 was calculated to be 0.011 cfs/mi^2. The areal flow for West Bayou Lacassine was calculated to be 0.048 cfs/mi^2. The average of these two areal flows was approximately 0.03 cfs/mi^2. With a watershed area of 107 mi^2, the calculated flow for Bayou Chene was 3.2 cfs.

Plots of measured chloride and conductivity (Figures 3.1 and 3.2) indicated that tidal dispersion was affecting water quality, particularly in the lower part of Bayou Lacassine. Values for the dispersion coefficients were developed by calibrating the model to match observed values of chloride and conductivity. The observed values of chloride and conductivity were lower in the middle of the system (BL-1 to BL-3) than in the upper end (EBL-2 to EBL-3). Based on observations during the reconnaissance and during the intensive survey and calculations of hydraulic residence time, it is assumed that the water in the middle of the system entered the system during a time when flows were higher and concentrations of chloride and conductivity were lower. Conversely, the water in the upper part of the system entered during low flow conditions when concentrations of chloride and conductivity were higher due to less dilution of the chlorinated effluent from the point source discharges (Town of Welsh and Lacassine High School). Because a steady state model cannot simulate inflow concentrations or flows that vary with time, the concentrations for the point source discharges were set to the observed values for the middle of the system (20 mg/L for chloride and 170 µmhos/cm for conductivity). Then the model was calibrated for chloride and conductivity in the middle and lower portion of the Bayou Lacassine system. Values for the dispersion coefficient were developed by an iterative process; the values were adjusted until modeled chloride concentrations were similar to measured concentrations. Modeled conductivity also matched measured concentrations well with these dispersion coefficients. The values of the dispersion coefficient ranged from 220 ft^2/sec at the Intracoastal Waterway to 8 ft^2/sec at river mile 9.0. The dispersion coefficient for all reaches upstream of river mile 9.0 was maintained at 8 ft^2/sec. The values of the dispersion coefficients are shown in Appendix D.

Field data, topographic maps, and aerial photos were used to develop depths and widths for the Bayou Lacassine system. Values of average depth were obtained from cross section measurements from the FTN intensive survey and from the LDEQ intensive survey of East Bayou Lacassine downstream of the Town of Welsh WWTP (LDEQ, 1994). These measured depths are shown on Figure 3.3 along with the depths used as model input. For widths, values were obtained from cross section measurements from the FTN and LDEQ surveys in the upper end of the system. In the lower part of the system, the stream was wide enough that widths were measured from USGS 7.5 minute topographic maps (using recent aerial photos to ensure that the

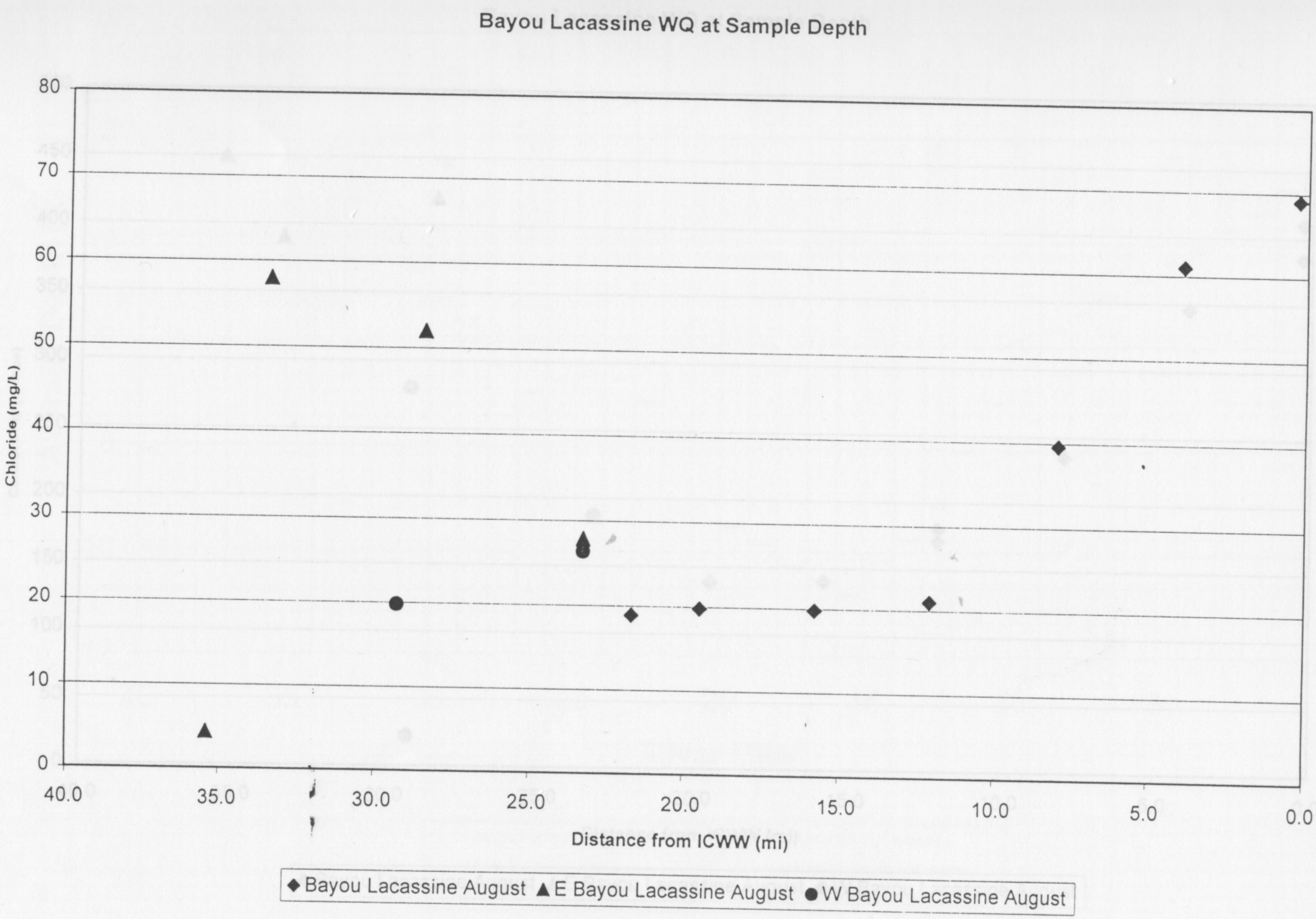


Figure 3.1. Plot of measured chloride vs river mile.

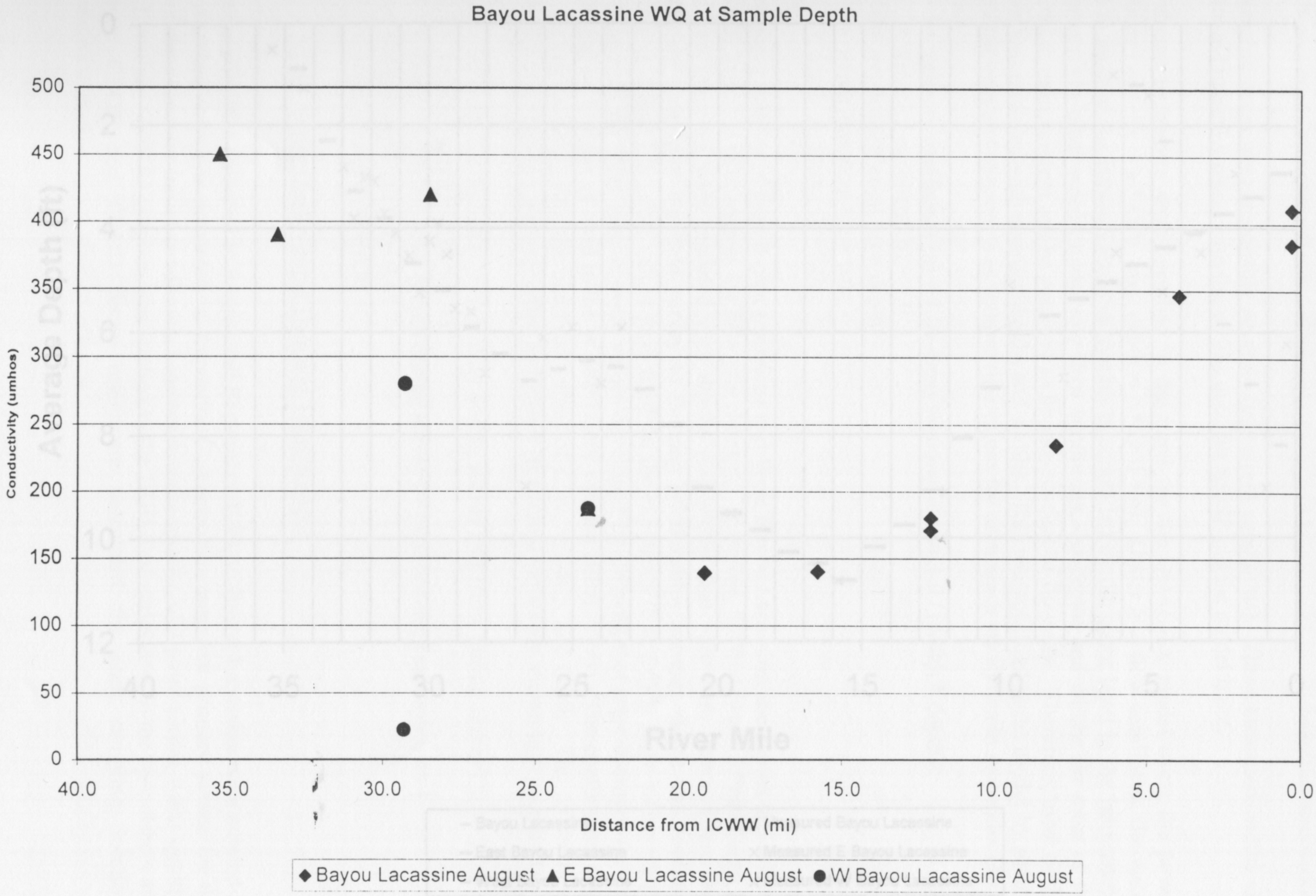


Figure 3.2. Plot of measured conductivity vs river mile.

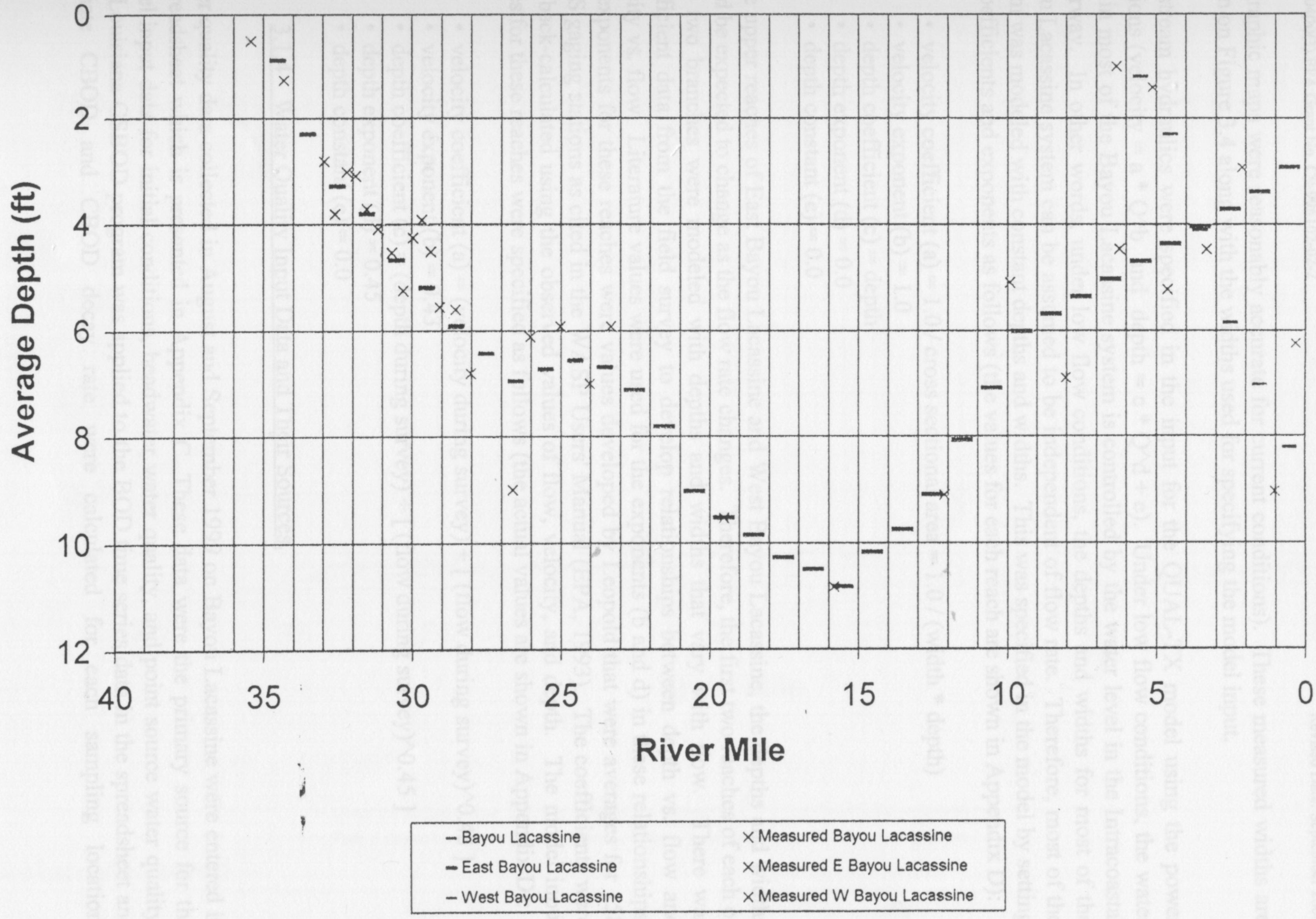


Figure 3.3 Channel depths used in model calibration.

topographic maps were reasonably accurate for current conditions). These measured widths are shown on Figure 3.4 along with the widths used for specifying the model input.

The stream hydraulics were specified in the input for the QUAL-TX model using the power functions (velocity = a * Q^b and depth = c * Q^d + e). Under low flow conditions, the water level in most of the Bayou Lacassine system is controlled by the water level in the Intracoastal Waterway. In other words, under low flow conditions, the depths and widths for most of the Bayou Lacassine system can be assumed to be independent of flow rate. Therefore, most of the system was modeled with constant depths and widths. This was specified in the model by setting the coefficients and exponents as follows (the values for each reach are shown in Appendix D):

- velocity coefficient (a) = 1.0 / cross sectional area = 1.0 / (width * depth)
- velocity exponent (b) = 1.0
- depth coefficient (c) = depth
- depth exponent (d) = 0.0
- depth constant (e) = 0.0

In the upper reaches of East Bayou Lacassine and West Bayou Lacassine, the depths and widths would be expected to change as the flow rate changes. Therefore, the first two reaches of each of these two branches were modeled with depths and widths that vary with flow. There was insufficient data from the field survey to develop relationships between depth vs. flow and velocity vs. flow. Literature values were used for the exponents (b and d) in these relationships. The exponents for these reaches were values developed by Leopold that were averages for 158 USGS gaging stations as cited in the WASP Users' Manual (EPA, 1993). The coefficients were then back-calculated using the observed values of flow, velocity, and depth. The model input values for these reaches were specified as follows (the actual values are shown in Appendix D):

- velocity coefficient (a) = (velocity during survey) ÷ [(flow during survey)^0.43]
- velocity exponent (b) = 0.43
- depth coefficient (c) = (depth during survey) ÷ [(flow during survey)^0.45]
- depth exponent (d) = 0.45
- depth constant (e) = 0.0

3.1.4 Water Quality Input Data and Their Sources.

Water quality data collected in August and September 1999 on Bayou Lacassine were entered in a spreadsheet which is presented in Appendix C. These data were the primary source for the model input data for initial conditions, headwater water quality, and point source water quality. The Louisiana GSBOD program was applied to the BOD time series data in the spreadsheet and ultimate CBOD and CBOD decay rate were calculated for each sampling location.

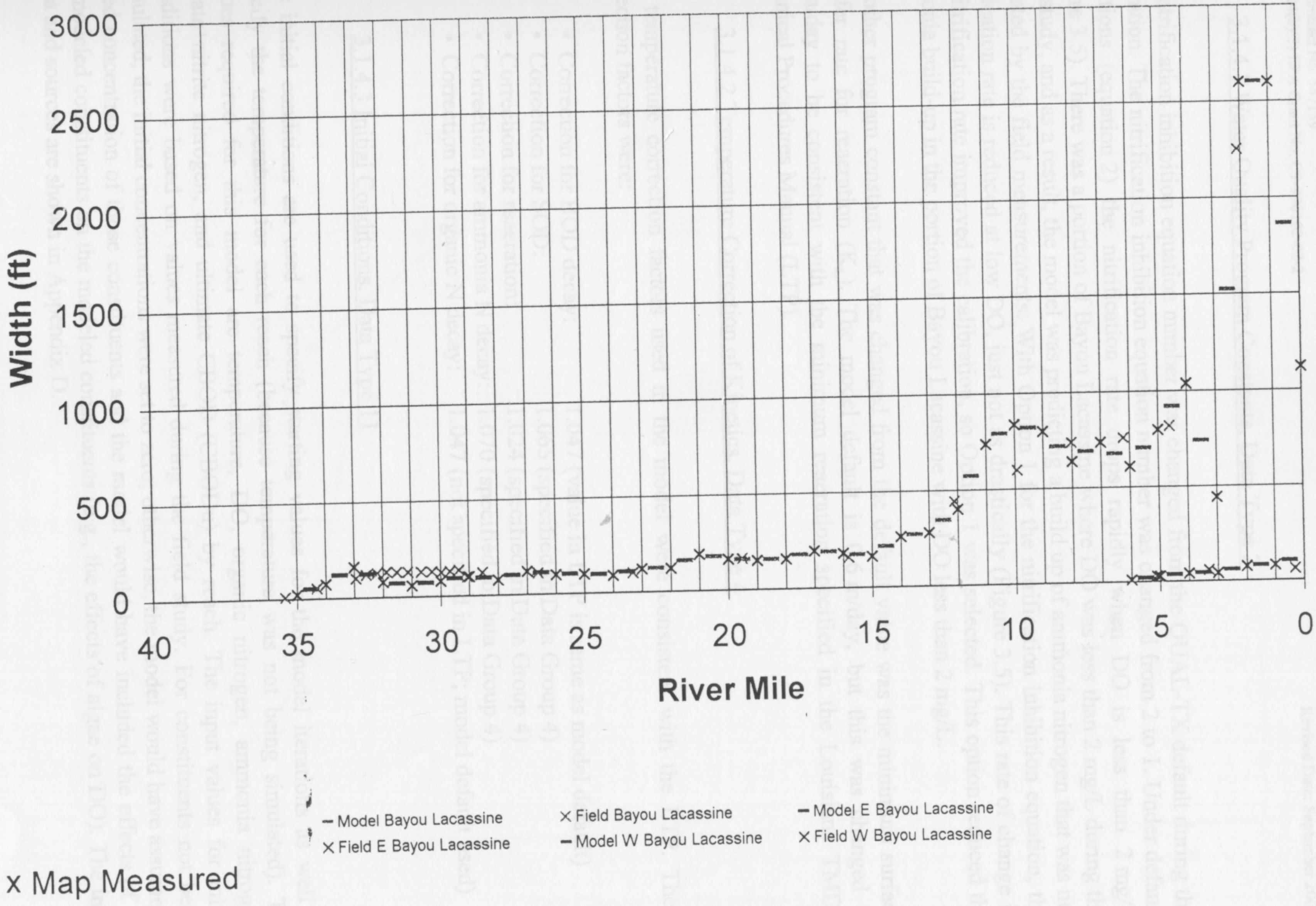


Figure 3.4 Channel widths used to develop model inputs.

3.1.4.1 Water Quality Program Constants, Data Type 3

The nitrification inhibition equation number was changed from the QUAL-TX default during the calibration. The nitrification inhibition equation number was changed from 2 to 1. Under default conditions (equation 2) the nitrification rate drops rapidly when DO is less than 2 mg/L (Figure 3.5). There was a portion of Bayou Lacassine where DO was less than 2 mg/L during the field study, and as a result, the model was predicting a build up of ammonia nitrogen that was not indicated by the field measurements. With Option 1 for the nitrification inhibition equation, the nitrification rate is reduced at low DO, just not as drastically (Figure 3.5). This rate of change in the nitrification rate improved the calibration, so Option 1 was selected. This option reduced the ammonia build-up in the portion of Bayou Lacassine with DO less than 2 mg/L.

The other program constant that was changed from the default value was the minimum surface transfer rate for reaeration (K_L). The model default is 0.6 m/day, but this was changed to 0.7 m/day to be consistent with the minimum reaeration specified in the Louisiana TMDL Technical Procedures Manual (LTP).

3.1.4.2 Temperature Correction of Kinetics, Data Type 4

The temperature correction factors used in the model were consistent with the LTP. These correction factors were:

- Correction for BOD decay: 1.047 (value in LTP is same as model default)
- Correction for SOD: 1.065 (specified in Data Group 4)
- Correction for reaeration: 1.024 (specified in Data Group 4)
- Correction for ammonia N decay: 1.070 (specified in Data Group 4)
- Correction for organic N decay: 1.047 (not specified in LTP; model default used)

3.1.4.3 Initial Conditions, Data Type 11

The initial conditions are used to specify starting values for the model iterations as well as specify the temperature for each reach (because temperature was not being simulated). The values required for this model are temperature, DO, organic nitrogen, ammonia nitrogen, nitrate+nitrite nitrogen, and ultimate CBOD (CBODu) by reach. The input values for initial conditions were based on values measured during the field study. For constituents not being simulated, the initial concentrations were set to zero; otherwise, the model would have assumed a fixed concentration of those constituents and the model would have included the effects of the unmodeled constituents on the modeled constituents (e.g., the effects of algae on DO). The input data and sources are shown in Appendix D.

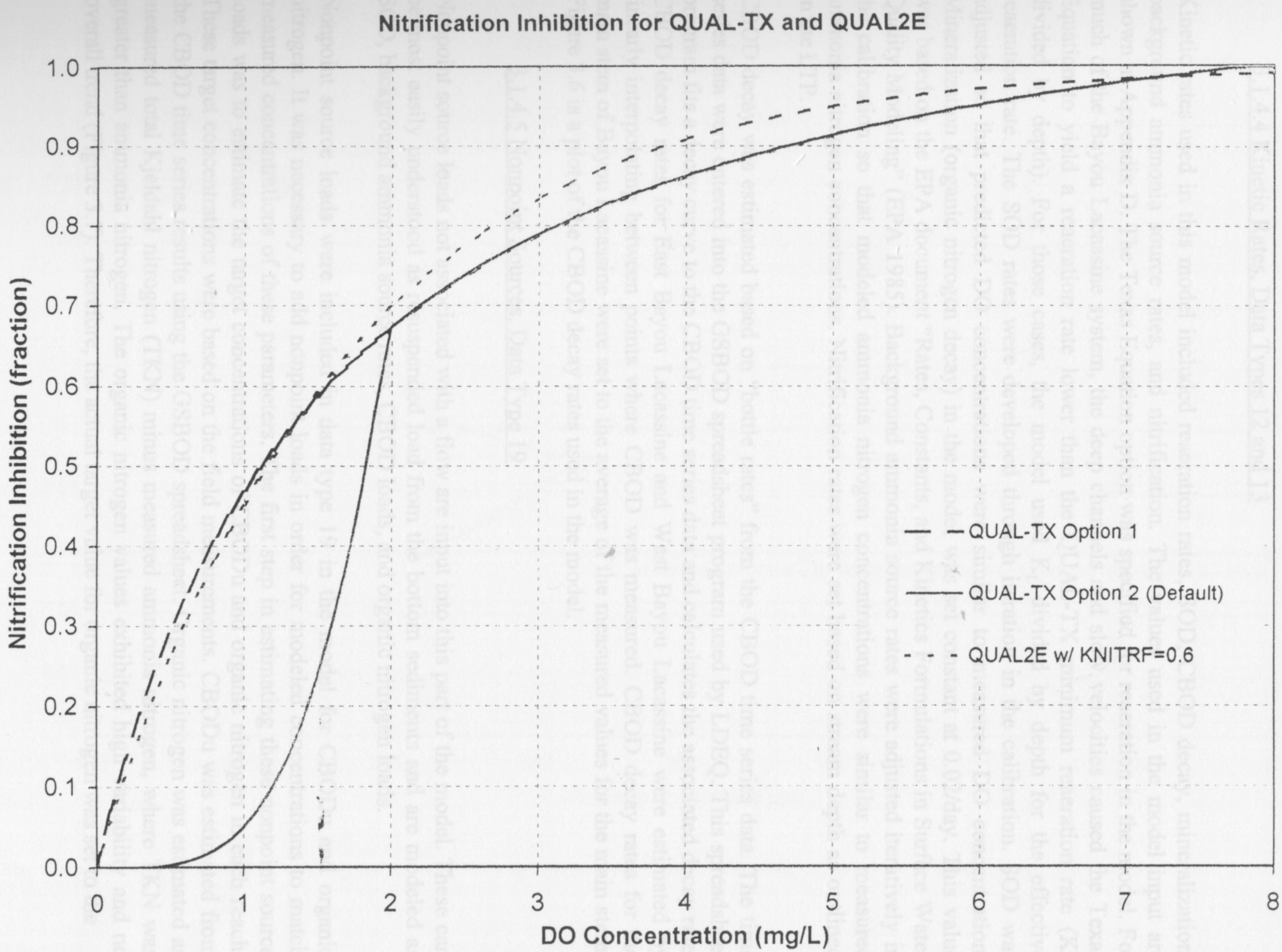


Figure 3.5. Comparison of nitrification inhibition equations for QUAL-TX.

3.1.4.4 Kinetic Rates, Data Types 12 and 13

Kinetic rates used in this model included reaeration rates, SOD, CBOD decay, mineralization, background ammonia source rates, and nitrification. The values used in the model input are shown in Appendix D. The Texas Equation option was specified for reaeration in the model. For much of the Bayou Lacassine system, the deep channels and slow velocities caused the Texas Equation to yield a reaeration rate lower than the QUAL-TX minimum reaeration rate (K_L divided by depth). For those cases, the model used K_L divided by depth for the effective reaeration rate. The SOD rates were developed through iteration in the calibration. SOD was adjusted so that predicted DO concentrations were similar to measured DO concentration. Mineralization (organic nitrogen decay) in the model was set constant at 0.02/day. This value was based on the EPA document "Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling" (EPA 1985). Background ammonia source rates were adjusted iteratively in the calibration so that modeled ammonia nitrogen concentrations were similar to measured ammonia nitrogen concentrations. Nitrification rates were set based on stream depth as outlined in the LTP.

CBOD decay was estimated based on "bottle rates" from the CBOD time series data. The time series data were entered into the GSBOD spreadsheet program used by LDEQ. This spreadsheet program fits a decay curve to the CBOD time series data and calculates the associated decay rate. CBOD decay rates for East Bayou Lacassine and West Bayou Lacassine were estimated by linearly interpolating between points where CBOD was measured. CBOD decay rates for the main stem of Bayou Lacassine were set to the average of the measured values for the main stem. Figure 3.6 is a plot of the CBOD decay rates used in the model.

3.1.4.5 Nonpoint Sources, Data Type 19

Nonpoint source loads not associated with a flow are input into this part of the model. These can be most easily understood as resuspended load from the bottom sediments and are modeled as SOD, background ammonia source rates, CBOD loads, and organic nitrogen loads.

Nonpoint source loads were included in data type 19 in the model for CBODu and organic nitrogen. It was necessary to add nonpoint loads in order for modeled concentrations to match measured concentrations of these parameters. The first step in estimating these nonpoint source loads was to estimate the target concentrations of CBODu and organic nitrogen in each reach. These target concentrations were based on the field measurements. CBODu was estimated from the CBOD time series results using the GSBOD spreadsheet. Organic nitrogen was estimated as measured total Kjeldahl nitrogen (TKN) minus measured ammonia nitrogen, where TKN was greater than ammonia nitrogen. The organic nitrogen values exhibited high variability and no overall trend (Figure 3.7). Therefore, the actual target value for organic nitrogen was set to the

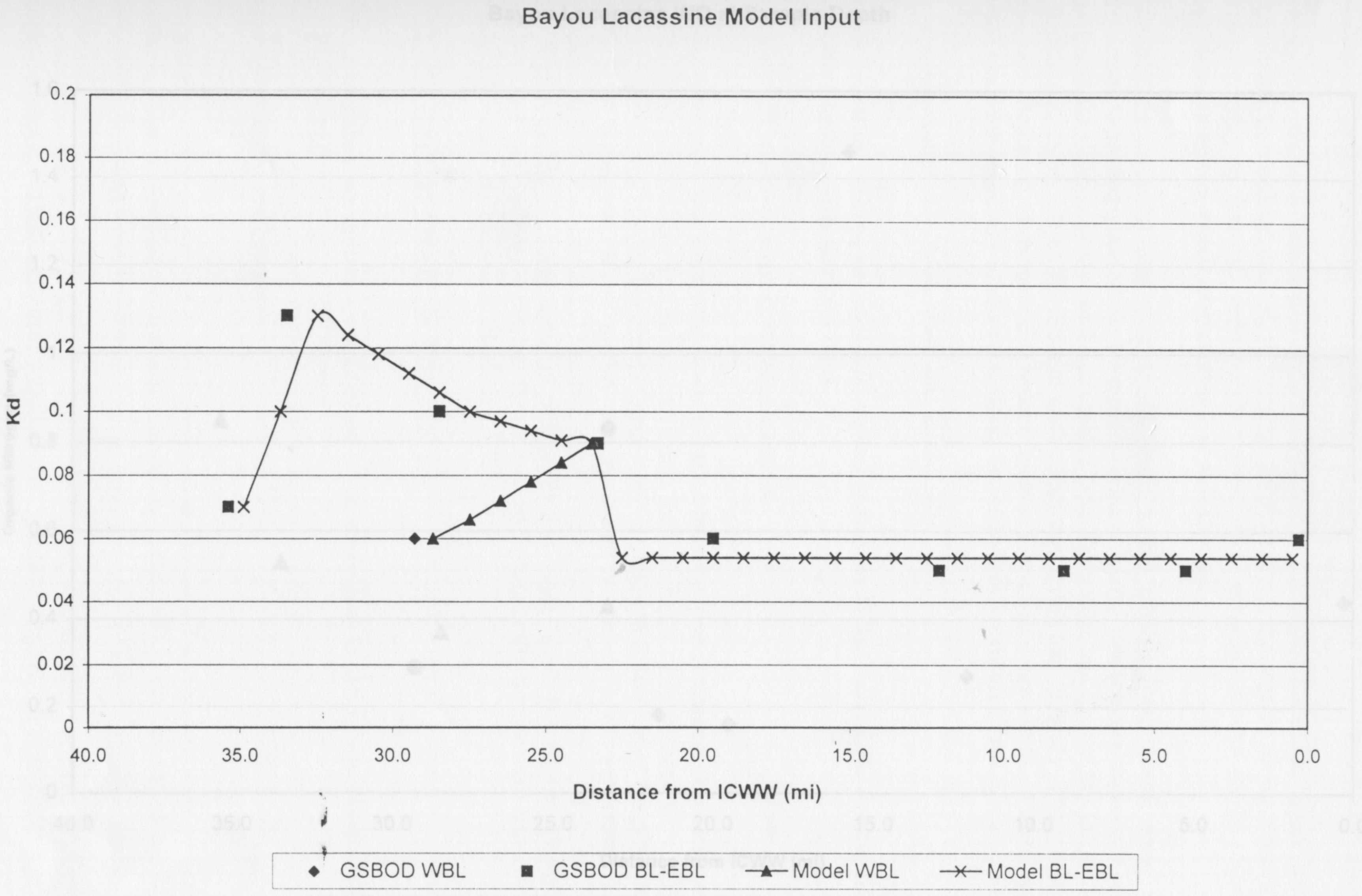


Figure 3.6. CBOD decay rates used in model.

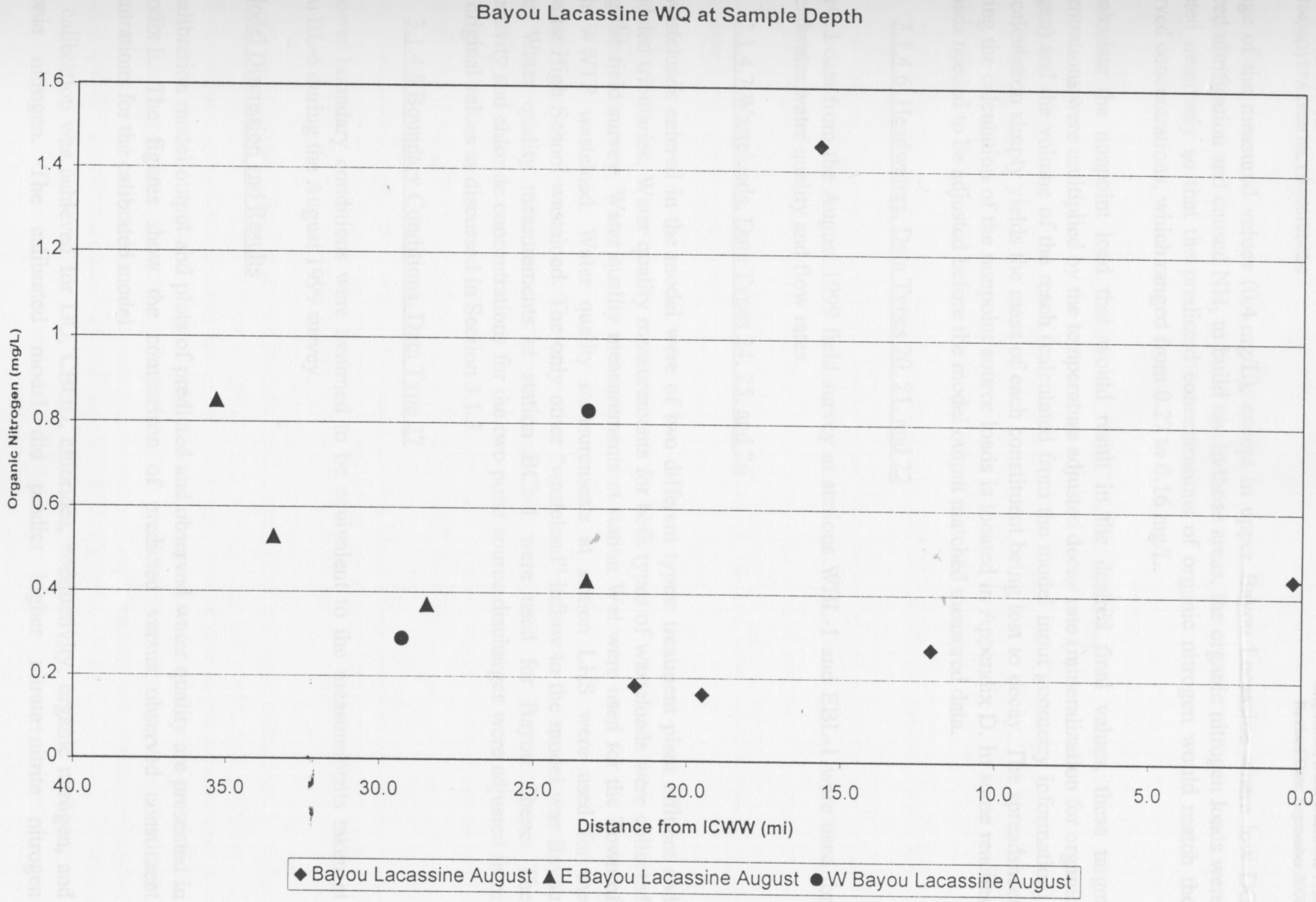


Figure 3.7. Calculated organic nitrogen concentrations from field survey.

average of the measured values (0.4 mg/L), except in upper Bayou Lacassine where low DO reduced nitrification and caused NH_3 to build up. In those areas, the organic nitrogen loads were adjusted iteratively so that the predicted concentrations of organic nitrogen would match the observed concentrations, which ranged from 0.27 to 0.16 mg/L.

To calculate the nonpoint load that would result in the desired final values, these target concentrations were multiplied by the temperature adjusted decay rate (mineralization for organic nitrogen) and the volume of the reach (calculated from the model input geometry information). This calculation simply yields the mass of each constituent being lost to decay. The spreadsheet showing the calculation of the nonpoint source loads is located in Appendix D. In some reaches the loads needed to be adjusted before the model output matched measured data.

3.1.4.6 Headwaters, Data Types 20, 21, and 22

Observed data from the August 1999 field survey at stations WBL-1 and EBL-1 were used for the headwater water quality and flow rates.

3.1.4.7 Wasteloads, Data Types 24, 25, and 26

The wasteloads entered in the model were of two different types: treatment plant effluent and unmodeled tributaries. Water quality measurements for both types of wasteloads were collected during the field survey. Water quality measurements at station Wel were used for the Town of Welsh WWTP wasteload. Water quality measurements at station LHS were used for the Lacassine High School wasteload. The only other “wasteload” inflow to the model was Bayou Chene. Water quality measurements at station BCh-1 were used for Bayou Chene. The conductivity and chloride concentrations for the two point source discharges were adjusted from these original values as discussed in Section 3.1.3.

3.1.4.8 Boundary Conditions, Data Type 27

The lower boundary conditions were assumed to be equivalent to the measurements taken at station BL-6 during the August 1999 survey.

3.2 Model Discussion and Results

The calibration model output and plots of predicted and observed water quality are presented in Appendix E. The figures show the comparison of predicted versus observed constituent concentrations for the calibrated model.

Good calibration was achieved for DO, CBOD, chlorides, conductivity, organic nitrogen, and ammonia nitrogen. The calibrated model did predict higher nitrate+nitrite nitrogen concentrations than were measured during the field study. This is a common phenomenon in DO water quality models. Nitrate+nitrite nitrogen concentrations were not calibrated because nitrate does not affect modeled DO concentrations.

4.0 WATER QUALITY PROJECTIONS

Since the calibrated model indicated that the summer DO criterion was not being met in East Bayou Lacassine and the upper part of Bayou Lacassine, three loading scenarios were performed in addition to the traditional summer and winter projections. These additional scenarios were:

a. No Load Scenario - No point source loads and no nonpoint source loads above background
b. No Discharge Scenario - No point source loads with the calibrated nonpoint source loads
c. No Nonpoint Source Scenario - Current permitted dischargers with no nonpoint source loads above background

Because the water quality standard for DO varies seasonally, each of these scenarios was run for both summer and winter conditions.

4.1 Critical Conditions

4.1.1 Seasonality and Margin of Safety

The Clean Water Act requires the consideration of seasonal variation of conditions affecting the constituent of concern, and the inclusion of a margin of safety (MOS) in the development of a TMDL. For the Bayou Lacassine TMDL, an analysis of LDEQ long-term ambient data was used to determine critical seasonal conditions. Explicit margins of safety of 20 % for point and 10% for non-point loading were used in developing the projection models.

Critical conditions for DO have been determined for the Mermentau Basin in previous TMDL studies. The analysis concluded that the critical conditions for stream DO concentrations occur during periods with negligible nonpoint runoff, low stream flow, and high stream temperature.

When the rainfall runoff (and nonpoint loading) and stream flow are high, turbulence is higher due to the higher flow and the stream temperature is lowered by the cooler precipitation and runoff. In addition, runoff coefficients are higher in cooler weather due to reduced evaporation and evapotranspiration, so that the high flow periods of the year tend to be the cooler periods. DO saturation values are, of course, much higher when water temperatures are cooler, but BOD decay rates are much lower. For these reasons, periods of high loading are periods of higher reaeration and DO but not necessarily periods of high BOD decay.

LDEQ interprets this phenomenon in its TMDL modeling by assuming that the annual nonpoint loading, rather than loading for any particular day, is responsible for the accumulated benthic blanket of the stream, which is, in turn, expressed as SOD and/or resuspended BOD in the model.

This accumulated loading has its greatest impact on the stream during periods of higher temperature and lower flow. The manmade portion of the NPS loading is the difference between the calibration load and the reference stream load where the calibration load is higher.

According to the LTP, critical summer conditions in DO TMDL projection modeling are simulated by using the annual 7Q10 flow or 0.1 cfs, whichever is higher, for all headwaters, and 90th percentile temperature for the summer season. Model loading is from point sources, perennial tributaries, SOD, and resuspension of sediments. Critical winter conditions are simulated by using the lowest of the monthly 7Q10 flows published for the winter months or 1.0 cfs, whichever is higher, for all headwaters, and 90th percentile temperature for the season. Again, model loading is from point sources, perennial tributaries, SOD, and resuspension of sediments. In addition, LDEQ assumes that all point sources are discharging at design capacity.

In reality, the highest temperatures occur in July-August, the lowest stream flows occur in October-November, and the maximum point source discharge occurs following a significant rainfall, i.e., high-flow conditions. The combination of these conditions plus the impact of other conservative assumptions regarding rates and loadings yields an implied MOS that is not quantified. Over and above this implied MOS, LDEQ typically reserves an explicit MOS of 20% for point and up to 10% for nonpoint loads to account for future growth and model uncertainty.

4.1.2 Hydrology

In accordance with the LTP, flows for the projection runs were based on 7Q10 conditions. There are no published 7Q10 flows for Bayou Lacassine or its tributaries. Negative flows at the USGS gage on Bayou Lacassine at Highway 14 make calculation of a 7Q10 flow at that point impossible.

Nearby streams with published 7Q10 values were examined to see if one of them could be used for estimating the 7Q10 flows for Bayou Lacassine based on the concept of similar streams. Bayou Wikoff was selected as a similar stream because it is also in the Mermentau River basin and the USGS flow gage near Rayne (08010500) has a drainage area similar to the drainage areas of each of the major stream inflows for the Bayou Lacassine model (East Bayou Lacassine, West Bayou Lacassine, and Bayou Chene).

To estimate 7Q10 flows for East and West Bayou Lacassine and Bayou Chene, areal 7Q10 flows (i.e., 7Q10 flows in cfs per mi^2) were determined for Bayou Wikoff. For the summer period (March – November), the published annual 7Q10 was used for the 7Q10 areal flow. For the winter period (December – February), a seasonal 7Q10 was calculated using historical flows available for the Bayou Wikoff station and then converted to a winter 7Q10 areal flow. The summer and winter 7Q10 areal flows were then multiplied by the published drainage areas for East and West Bayou Lacassine and Bayou Chene. These calculations are shown in Appendix F. The resulting estimated summer and winter 7Q10 flows for these 3 streams (East Bayou Lacassine, West Bayou Lacassine, and Bayou Chene) were all less than 0.1 cfs. Therefore, based on guidance in the LTP, the flow rates for these 3 streams were set to 0.1 cfs for the summer projections and 1.0 cfs for the winter projection.

Flows for the other unmodeled tributaries (Unnamed Tributaries 1 and 2 and Thornwell Drainage Canal) were set to zero based on their small drainage areas. Each of the two wastewater treatment plant flows were set to 125% of their design flow in order to incorporate an explicit 20% margin of safety for the point source wasteload allocations.

4.1.3 Water Quality Input Data and Their Sources

The projection runs used the same hydraulic and kinetic coefficients as in the calibration run (e.g., the same velocity and depth coefficients, decay rates, temperature adjustment factors, etc.). The only model inputs that were changed from the calibration to the projection runs were the temperature, inflow rates, inflow water quality, and NPS loads.

4.1.3.1 Initial Conditions, Data Type 11

The primary input that was specified in the initial conditions was the water temperature, which was set to the 90th percentile temperature for each season. The 90th percentile temperatures were calculated from LDEQ historical data for Bayou Lacassine at Highway 14. The seasons were defined the same as for the DO criteria (March through November for summer and December through February for winter). Calculations for the 90th percentile temperatures are shown in Appendix G. The initial DO concentrations were set to 90% of the saturation value at the seasonal temperatures. All other initial conditions were the same as in the calibration run. For each of the model inputs that was changed from the calibration to the projections, the input values and data sources are shown in Appendix H.

4.1.3.2 Nonpoint Source Loads, Data Type 19

For the projection runs, the nonpoint source (NPS) loads from the calibration run were divided between natural NPS loads and manmade NPS loads. This was done by estimating the natural NPS loads and then designating the remainder of the NPS loads from the calibration run as manmade NPS loads. When dividing NPS loads between natural and manmade, the total NPS loading is considered to be the sum of SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen.

Initially, the natural nonpoint source loads were set to the median values from the reference stream data (Smythe, 1997). These values are shown in Table 1 in Appendix I. However, in many segments, these natural loads were greater than the loads used in the calibration (Table 2 in Appendix I). Most of these segments were in portions of the system that were heavily impacted by agriculture, so it was concluded that the initial natural loads were not reasonable. As a guideline, LDEQ proposed that in the portions of the system heavily impacted by agriculture, the manmade NPS loads could account for as much as half of the total NPS load. Using this guideline, the maximum natural NPS load was estimated as 1.0 g/m^2/day of oxygen demand for

West Bayou Lacassine and 1.5 $g/m^2/day$ of oxygen demand for East Bayou Lacassine and Bayou Lacassine (Table 3 in Appendix I). Where the NPS loads used in the calibration were less than the natural NPS loads, the NPS loads from the calibration were used as natural NPS loads.

For the no load scenario and the no NPS scenario, the manmade NPS loads were eliminated completely. Therefore, for these two scenarios, each of the 4 components of the NPS loading was set to the values corresponding to the natural NPS loads. The individual components of the NPS loading are SOD (data type 12), benthic release of ammonia nitrogen (data type 13), mass loads of CBODu (data type 19), and mass loads of organic nitrogen (data type 19). The input values for each of the NPS components is shown in Appendix H.

For the no discharge scenario, the NPS loads were set to the same values as in the calibration run. For the summer and winter projections, the manmade NPS loads were reduced as necessary to meet the water quality standards for DO. The input values for each of the NPS components for all of the projection runs are shown in Appendix H.

4.1.3.3 Headwaters, Data Types 20-22

Input values for the headwater inflows (East and West Bayou Lacassine) were the same in the projections as in the calibration run except for the flow rates, temperatures, and DO values. The flow rates were set to 0.1 cfs for summer and 1.0 cfs for winter as discussed in Section 4.1.2. The temperatures were set to the 90th percentile seasonal temperature (same as the values specified in the initial conditions). The DO concentrations were set to 90% saturation at the 90th percentile seasonal temperature in accordance with the LTP. The values for these inputs for the projection runs are shown in Appendix H.

4.1.3.4 Wasteloads and Unmodeled Tributaries, Data Types 24-26

Flow rates for the point source discharges were based on current design flows. For the 3 projections that include point sources (no NPS scenario, summer projection, and winter projection), the point source flow rates were set to 125% of their current design flow in order to incorporate an explicit 20% margin of safety. For the other 2 scenarios (no load scenario and no discharge scenario), the point source flow rates were set to zero.

For the no NPS scenario, concentrations for the point source discharges were based on existing permit limits and guidance in the LTP. The temperatures for both point sources were set to the 90th percentile seasonal temperature (same as the values specified in the initial conditions). Based on guidance from LDEQ, the DO concentrations for the point sources were set to 5 mg/L for the Town of Welsh and 2 mg/L for Lacassine High School. CBODu concentrations for both point sources were set to their existing $CBOD_5$ permit limits times an assumed CBODu to $CBOD_5$ ratio of 2.3. The ammonia nitrogen concentration for Lacassine High School was set to 15 mg/L, which is typical of effluent from secondary treatment according to the LTP. The ammonia nitrogen concentration for the Town of Welsh was set to 10 mg/L based on the LTP and their existing CBOD limit. Based on LDEQ experience, effluent from mechanical treatment systems typically has a organic nitrogen to ammonia nitrogen ratio of 1:2, while effluent from pond systems typically has a organic nitrogen to ammonia nitrogen ratio of 2:1. Because Lacassine High School has a package plant (i.e., a mechanical system), their organic nitrogen concentration was set to 7.5 mg/L (half of their ammonia nitrogen concentration). Because the Town of Welsh has a pond system for treatment, their organic nitrogen concentration was set to 20 mg/L (twice their ammonia nitrogen concentration). Nitrate+nitrite nitrogen concentrations were set to the analytical detection limit (0.05 mg/L) based on typical values for municipal wastewater (Metcalf and Eddy, 1991).

For the summer projection and winter projection, the point source input values were the same as for the no NPS scenario except that discharge concentrations of CBODu, ammonia nitrogen, and organic nitrogen were reduced as needed for predicted DO values to be at or above the water quality standard. Also, the ratio of organic nitrogen to ammonia nitrogen was changed for the Town of Welsh because it was assumed that they would need to upgrade from a pond system to a mechanical system in order to meet the CBOD and ammonia nitrogen limits being used in the model. In both the summer and winter projections, the organic nitrogen for the Town of Welsh was assumed to be half of the ammonia nitrogen (rather than twice the ammonia nitrogen).

The flow rate and concentrations for Bayou Chene were developed on the same basis as for the headwaters (see previous section). Input values for Bayou Chene and the point source discharges are shown in Appendix H.

4.1.3.5 Downstream Boundary Conditions (Data Type 27)

Input values for the downstream boundary conditions were the same in the projections as in the calibration except for temperature and DO. The temperatures were set to the 90th percentile seasonal temperatures (the same as the initial temperatures). The DO values were set to 70% of saturation for the summer runs and 80% of saturation for the winter runs. The percent DO saturation for the summer runs was based on 1999 FTN field data collected during summer conditions. The percent DO saturation for the winter runs was based on historical data collected by Lacassine National Wildlife Refuge personnel during the months of December through February. These data and the values specified in the model input are shown in Appendix H.

4.2 Model Discussion and Results

The model output from the projection runs is presented in the appendices. For the summer and winter projections, complete printouts of the model output are included. For the other three scenarios, only the input files and graphs of predicted DO are presented.

4.2.1 No Load Scenario

In this scenario, the point source discharges were eliminated and the manmade NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were eliminated. Therefore, the model inputs for NPS loadings were set to the values used to represent natural NPS loadings (see discussion above concerning natural and manmade NPS loadings). The results of these simulations showed that the water quality standards for DO were met for both summer and winter conditions. The input files and the graphs of predicted DO for the no load scenario are included in Appendix J.

4.2.2 No Discharge Scenario

In this scenario, the point source discharges were eliminated and the NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were set to the values used in the calibration run. For the summer simulation, the predicted DO was below the water quality standard in the upper portion of Bayou Lacassine and most of East Bayou Lacassine but above the standard in other parts of the system. For the winter simulation, the predicted DO was below the standard in Bayou Lacassine near the confluence of Bayou Chene but above the standard in other parts of the system. The input files and the graphs of predicted DO for the no discharge scenario are included in Appendix K.

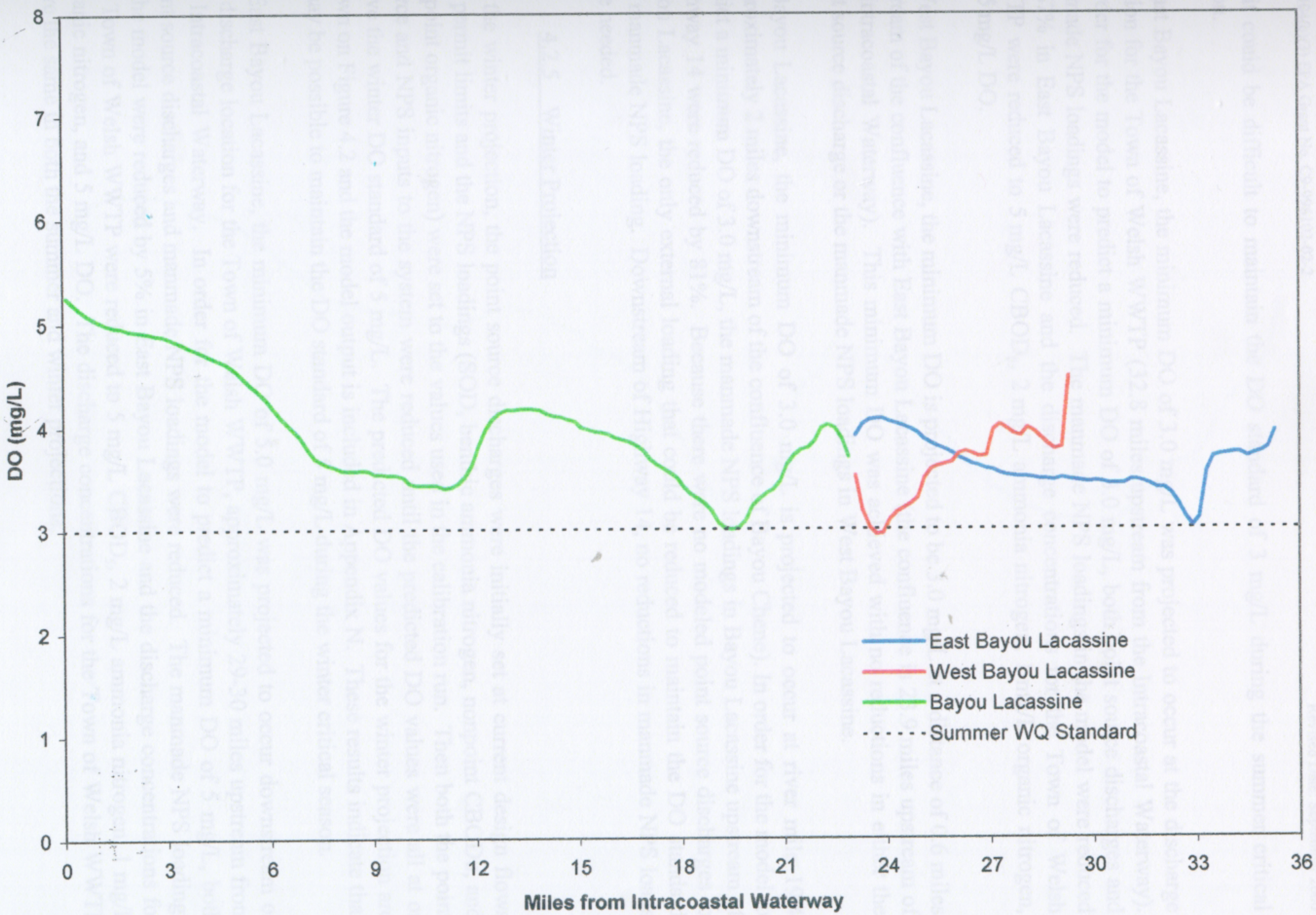
4.2.3 No NPS Scenario

In this scenario, the point source discharges were set at current design flows and permit limits and the manmade NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were eliminated. Therefore, the model inputs for NPS loadings were set to the values used to represent natural NPS loadings (see discussion above concerning natural and manmade NPS loadings). For the summer simulation, the predicted DO values were below the water quality standard near the discharge from the Town of Welsh WWTP but above the standard for all other parts of the system. For the winter simulation, the DO standard was met throughout the system. The input files and the graphs of predicted DO for the no NPS scenario are included in Appendix L.

4.2.4 Summer Projection

For the summer projection, the point source discharges were initially set at current design flows and permit limits and the NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were set to the values used in the calibration run. Then both the point source and NPS inputs to the system were reduced until the predicted DO values were all at or above the summer DO standard of 3 mg/L. The predicted DO values for the summer projection are shown on Figure 4.1 and the model output is included in Appendix M. These results indicate

Figure 4.1. Predicted DO for Summer Projection



that it could be difficult to maintain the DO standard of 3 mg/L during the summer critical season.

In East Bayou Lacassine, the minimum DO of 3.0 mg/L was projected to occur at the discharge location for the Town of Welsh WWTP (32.8 miles upstream from the Intracoastal Waterway). In order for the model to predict a minimum DO of 3.0 mg/L, both point source discharges and manmade NPS loadings were reduced. The manmade NPS loadings in the model were reduced by 67% in East Bayou Lacassine and the discharge concentrations for the Town of Welsh WWTP were reduced to 5 mg/L $CBOD_5$, 2 mg/L ammonia nitrogen, 1 mg/L organic nitrogen, and 5 mg/L DO.

In West Bayou Lacassine, the minimum DO is projected to be 3.0 mg/L at a distance of 0.6 miles upstream of the confluence with East Bayou Lacassine (the confluence is 23.9 miles upstream of the Intracoastal Waterway). This minimum DO was achieved with no reductions in either the point source discharge or the manmade NPS loadings in West Bayou Lacassine.

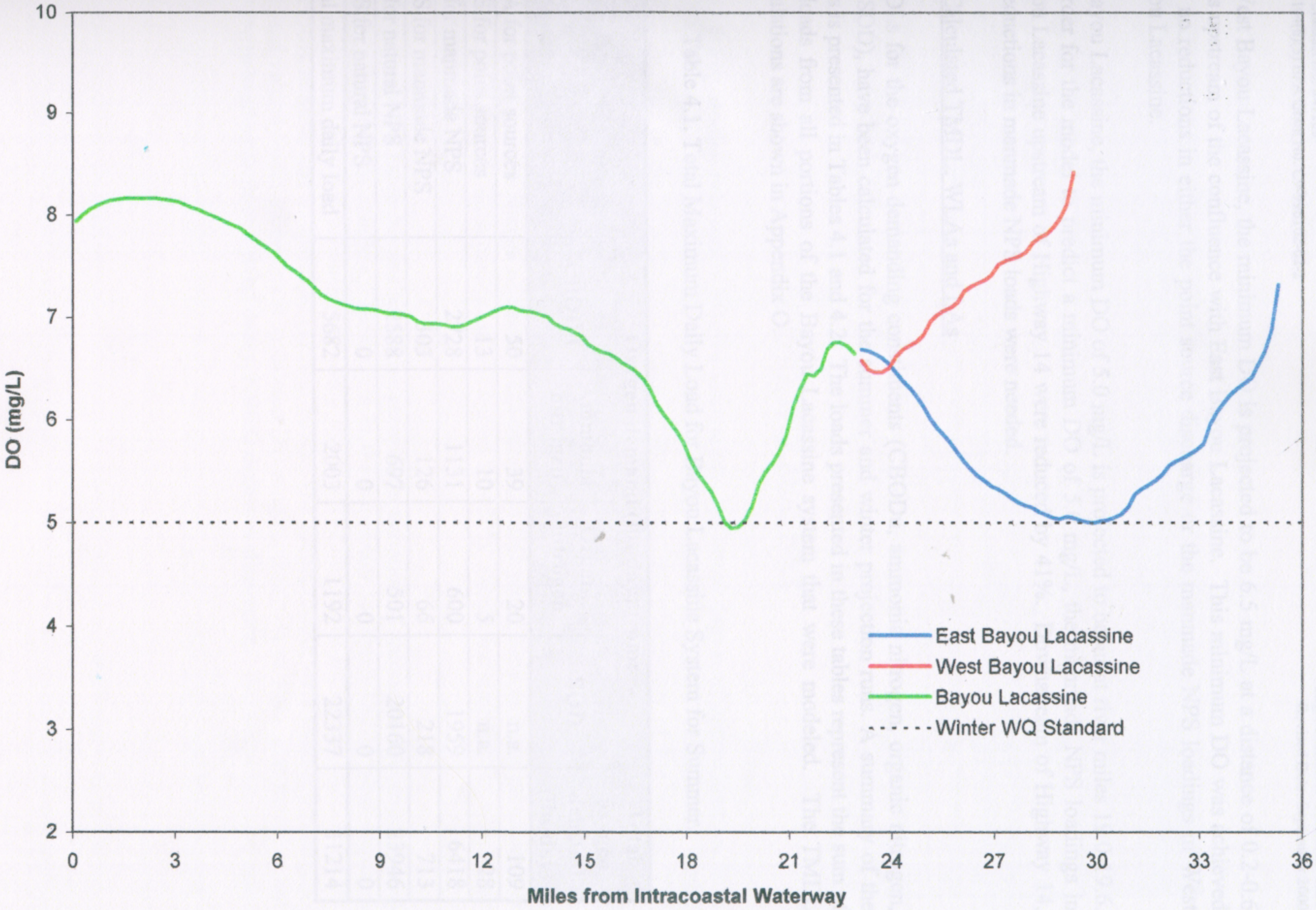
In Bayou Lacassine, the minimum DO of 3.0 mg/L is projected to occur at river mile 19.4 (approximately 2 miles downstream of the confluence of Bayou Chene). In order for the model to predict a minimum DO of 3.0 mg/L, the manmade NPS loadings in Bayou Lacassine upstream of Highway 14 were reduced by 81%. Because there were no modeled point source discharges to Bayou Lacassine, the only external loading that could be reduced to maintain the DO standard was manmade NPS loading. Downstream of Highway 14, no reductions in manmade NPS loads were needed.

4.2.5 Winter Projection

For the winter projection, the point source discharges were initially set at current design flows and permit limits and the NPS loadings (SOD, benthic ammonia nitrogen, nonpoint CBODu, and nonpoint organic nitrogen) were set to the values used in the calibration run. Then both the point source and NPS inputs to the system were reduced until the predicted DO values were all at or above the winter DO standard of 5 mg/L. The predicted DO values for the winter projection are shown on Figure 4.2 and the model output is included in Appendix N. These results indicate that it may be possible to maintain the DO standard of 5 mg/L during the winter critical season.

In East Bayou Lacassine, the minimum DO of 5.0 mg/L was projected to occur downstream of the discharge location for the Town of Welsh WWTP, approximately 29-30 miles upstream from the Intracoastal Waterway. In order for the model to predict a minimum DO of 5 mg/L, both point source discharges and manmade NPS loadings were reduced. The manmade NPS loadings in the model were reduced by 5% in East Bayou Lacassine and the discharge concentrations for the Town of Welsh WWTP were reduced to 5 mg/L $CBOD_5$, 2 mg/L ammonia nitrogen, 1 mg/L organic nitrogen, and 5 mg/L DO. The discharge concentrations for the Town of Welsh WWTP were the same in both the summer and winter projections.

Figure 4.2. Predicted DO for Winter Projection



In West Bayou Lacassine, the minimum DO is projected to be 6.5 mg/L at a distance of 0.2-0.6 miles upstream of the confluence with East Bayou Lacassine. This minimum DO was achieved with no reductions in either the point source discharge or the manmade NPS loadings in West Bayou Lacassine.

In Bayou Lacassine, the minimum DO of 5.0 mg/L is projected to occur at river miles 19.0-19.6. In order for the model to predict a minimum DO of 5.0 mg/L, the manmade NPS loadings in Bayou Lacassine upstream of Highway 14 were reduced by 41%. Downstream of Highway 14, no reductions in manmade NPS loads were needed.

4.3 Calculated TMDL, WLAs and LAs

TMDLs for the oxygen demanding constituents (CBODu, ammonia nitrogen, organic nitrogen, and SOD), have been calculated for the summer and winter projection runs. A summary of the loads is presented in Tables 4.1 and 4.2. The loads presented in these tables represent the sum of the loads from all portions of the Bayou Lacassine system that were modeled. The TMDL calculations are shown in Appendix O.

Table 4.1. Total Maximum Daily Load for Bayou Lacassine System for Summer.

	Oxygen demand (lbs/day) from:				**Total oxygen demand (lbs/day)**
	CBODu	**Ammonia nitrogen**	**Organic nitrogen**	**SOD**	
WLA for point sources	50	39	20	n.a.	109
MOS for point sources	13	10	5	n.a.	28
LA for manmade NPS	2728	1131	600	1959	6418
MOS for manmade NPS	303	126	66	218	713
LA for natural NPS	2588	697	501	20160	23946
MOS for natural NPS	0	0	0	0	0
Total maximum daily load	5682	2003	1192	22337	31214

Table 4.2. Total Maximum Daily Load for Bayou Lacassine System for Winter.

	Oxygen demand (lbs/day) from:				**Total oxygen demand (lbs/day)**
	CBODu	**Ammonia nitrogen**	**Organic nitrogen**	**SOD**	
WLA for point sources	39	30	15	n.a.	84
MOS for point sources	10	8	4	n.a.	22
LA for manmade NPS	3506	1606	691	4624	10427
MOS for manmade NPS	390	178	77	514	1159
LA for natural NPS	2636	875	528	25035	29074
MOS for natural NPS	0	0	0	0	0
Total maximum daily load	6581	2697	1315	30173	40766

5.0 SENSITIVITY ANALYSES

All modeling studies necessarily involve uncertainty and some degree of approximation. It is therefore of value to consider the sensitivity of the model output to changes in model coefficients, and in the hypothesized relationships among the parameters of the model. The QUAL-TX model allows multiple parameters to be varied with a single run. The model adjusts each parameter up or down by the percentage given in the input set. The rest of the parameters listed in the sensitivity section are held at their original projection value. Thus the sensitivity of each parameter is reviewed separately. A sensitivity analysis was performed on the summer projection. The percent change of the model's minimum DO projections to these parameters is presented in Table 5.1. Each parameter was varied by ∀30%, except for temperature, which was varied ∀2ºC.

Values reported in Table 5.1 are sorted by percentage variation of minimum DO from largest percentage variation to smallest. Reaeration is the parameter to which DO is most sensitive (34% to 43%). The other parameters creating major variations in the minimum DO values are SOD (30% to 37%) and temperature (17% to 20%). The model results were slightly sensitive to depth and velocity with variations in predicted DO ranging from 3% to 10%. The model is not sensitive to headwater flow, CBOD decay, NBOD decay, or dispersion.

Table 5.1. Summary of Results of Sensitivity Analysis

Input Parameter	Parameter Change	Predicted Minimum DO (mg/L)	Percent Change in Predicted DO
Baseline (summer projection run)		3.0	NA
Dispersion	– 30%	3.0	< 1%
Dispersion	+ 30%	3.0	< 1%
CBOD decay rate	– 30%	3.0	< 1%
Headwater flow rate	– 30%	3.0	< 1%
Nitrification rate	– 30%	3.0	< 1%
Headwater flow rate	+ 30%	3.0	< 1%
Nitrification rate	+ 30%	2.9	3%
CBOD decay rate	+ 30%	2.9	3%
Velocity	– 30%	3.1	3%
Depth	– 30%	3.1	3%
Velocity	+ 30%	2.7	10%
Depth	+ 30%	2.7	10%
Temperature	– 30%	3.5	17%
Temperature	+ 30%	2.4	20%
SOD	– 30%	3.9	30%
Reaeration	+ 30%	4.0	33%
SOD	+ 30%	1.9	37%
Reaeration	– 30%	1.7	43%

6.0 CONCLUSIONS

Based on this modeling, maintaining the summer water quality standard for DO in the Bayou Lacassine system would require significant reductions of oxygen demanding loads to East Bayou Lacassine and the portion of Bayou Lacassine upstream of Highway 14. These reductions include an upgrade of the Town of Welsh WWTP as well as reductions of manmade nonpoint source loads from the watershed. These reductions are summarized below in Table 6.1.

Table 6.1. Treatment Plant Upgrades and Manmade NPS Load Reductions Required to Meet DO Standards in Summer and Winter.

	Town of Welsh WWTP	Lacassine High School WWTP	Manmade Nonpoint Source Loads			
			East Bayou Lacassine	**West Bayou Lacassine**	**Bayou Lacassine upstream of Hwy 14**	**Bayou Lacassine downstream of Hwy 14**
Summer	Upgrade*	None	67%	0%	81%	0%
Winter	Upgrade*	None	5%	0%	41%	0%

* Upgrade to discharge concentrations of 5 mg/L $CBOD_5$, 2 mg/L ammonia nitrogen, 1 mg/L organic nitrogen, and 5 mg/L DO.

LDEQ will work with other agencies such as local Soil Conservation Districts to implement agricultural best management practices in the watershed through the 319 programs. LDEQ will also continue to monitor the waters to determine whether standards are being attained.

In accordance with Section 106 of the federal Clean Water Act and under the authority of the Louisiana Environmental Quality Act, the LDEQ has established a comprehensive program for monitoring the quality of the state's surface waters. The LDEQ Surveillance Section collects surface water samples at various locations, utilizing appropriate sampling methods and procedures for ensuring the quality of the data collected. The objectives of the surface water monitoring program are to determine the quality of the state's surface waters, to develop a long-term data base for water quality trend analysis, and to monitor the effectiveness of pollution controls. The data obtained through the surface water monitoring program is used to develop the state’s biennial 305(b) report (Water Quality Inventory) and the 303(d) list of impaired waters. This information is also utilized in establishing priorities for the LDEQ nonpoint source program.

The LDEQ has implemented a watershed approach to surface water quality monitoring. Through this approach, the entire state is sampled over a five-year cycle with two targeted basins sampled each year. Long-term trend monitoring sites at various locations on the larger rivers and Lake Pontchartrain are sampled throughout the five-year cycle. Sampling is conducted on a monthly basis or more frequently if necessary to yield at least 12 samples per site each year. Sampling sites are located where they are considered to be representative of the waterbody. Under the current monitoring schedule, targeted basins follow the TMDL priorities. In this manner, the first TMDLs will have been implemented by the time the first priority basins will be monitored again in the second five-year cycle. This will allow the LDEQ to determine whether there has been any improvement in water quality following implementation of the TMDLs. As the monitoring results are evaluated at the end of each year, waterbodies may be added to or removed from the 303(d)list. The sampling schedule for the first five-year cycle is shown below.

1998 – Mermentau and Vermilion-Teche Basins

1999 – Calcasieu and Ouachita River Basins
2000 – Barataria and Terrebonne Basins
2001 – Lake Pontchartrain Basin and Pearl River Basin
2002 – Red and Sabine River Basins
(Atchafalaya and Mississippi Rivers will be sampled continuously.)
Mermentau and Vermilion-Teche Basins will be sampled again in 2003.

7.0 REFERENCES

Bowie, G.L., et. al. 1985. Rates, Constants, and Kinetics Formulations in Surface Water Quality Modeling (Second Edition). Env. Res. Lab., USEPA, EPA/600/3-85/040. Athens, GA: 1985.

EPA. 1993. Water Quality Analysis Simulation Program – WASP. User's Manual. Version 5.1.

LDEQ. 1991. Survey Report for the Reconnaissance Survey of East Bayou Lacassine at Welsh, Louisiana. Prepared by Gibson Asuquo et al. Baton Rouge, LA: November 1991.

LDEQ. 1993. State of Louisiana Nonpoint Source Assessment Report. Baton Rouge, LA: November 1993.

LDEQ. 1994. Survey Report for the Intensive Survey of East Bayou Lacassine at Welsh, Louisiana. Prepared by Gibson Asuquo. Baton Rouge, LA: April 1994.

LDEQ. 1998a. 1998 305 (b) Appendix C Table. Printed from Louisiana Department of Environment Quality website.

LDEQ. 1998b. Dissolved Oxygen Use Attainability Analysis, Mermentau River Basin. Baton Rouge, LA: May, 1998.

LDEQ. 1999a. Environment Regulatory Code. Part IX. Water Quality Regulations. Chapter 11. Surface Water Quality Standards. § 1123. Numerical Criteria and Designated Uses.

LDEQ. 199b. Bayou Nezpique Watershed TMDL for Dissolved Oxygen. Baton Rouge, LA: October 1999 (revised).

Lee, F.N., D. Everett, and M. Forbes. Lowflow Data for USGS Sites through 1993. Report prepared for LDEQ. March 1997.

Metcalf and Eddy. 1991. Wastewater Engineering, Treatment, Disposal, Reuse (Third Edition). McGraw-Hill, Inc. New York, NY. 1991.

Shoemaker, L., et. al. Compendium of Tools for Watershed Assessment and TMDL Development. Office of Wetland, Oceans, and Watersheds, USEPA, EPA841-B-97-006. Washington, DC. May, 1997.

Smythe, E. deEtte. Overview of the 1995 Reference Streams. Louisiana Department of Environmental Quality. Baton Rouge, LA: August 15, 1997.

Texas Water Commission. QUAL-TX User's Manual (Version 3.3). Water Quality Division, Water Quality Standards and Evaluation Section, Water Quality Evaluation Unit. Austin, TX: December 3, 1990.

USGS. 1971. Drainage Area of Louisiana Streams. Basic Records Report No. 6. Prepared by US Geological Survey in cooperation with Louisiana Department of Transportation and Development Baton Rouge, LA: 1971 (Reprinted 1991).

Waldon, M. C., R. K. Duerr, and M.U. Aguillard. Louisiana Total Maximum Daily Load Technical Procedures. Louisiana Department of Environmental Quality. Baton Rouge, LA. Revised 1999.